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Mediterranean farmers' understandings of 'good soil management' and 'good farmer' identity in the context of conservation agriculture

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ABSTRACT

Mediterranean agriculture is increasingly threatened by soil degradation and climate change. Conservation agriculture (CA) is a farming approach characterized by reduced soil disturbance, soil cover, and crop rotation that provides agronomic, economic, and environmental benefits to farmers, but which is not yet widespread in the Mediterranean region. To investigate the sociocultural aspects of CA adoption, we examined farmers' understandings of 'good soil management' and a 'good farmer' identity. We employed network analysis to visualize and compare farmers' mental models of these concepts and how they differed according to farmers' tillage practices. We found that crop rotation is a prominent concept cognitively tied to fertilizer application, bridging conventional and reduced tillage practices. CA farmers' mental models of soil management are more complex than conventional farmers'. Demonstrating productivity and having experience and knowledge were the most prominent aspects of farmers' understanding of a 'good farmer'. For CA farmers, this was tied to environmental responsibility and innovation, whereas for conventional farmers, a set of best practices including tillage and the use of mineral fertilizers, was valued more highly. CA may compete with held understandings concerning soil management among conventional farmers. CA adoption programmes could be better tailored to align with their cultural values.

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1. Introduction

In the Mediterranean region, agriculture is the dominant land use and a major source of income for rural people (Iglesias et al., 2011). However, climate change poses a major risk for the Mediterranean agricultural sector in terms of declining yields, reduced crop quality, and increased yield variability for most crops (Cramer et al., 2018; Mediterranean experts on Climate and environmental Change [MedECC], 2020). Climate change-induced decreases in precipitation or increases in heavy rainfall events can lead to drought stress, flooding of crops, and water erosion (Iglesias et al., 2011). These risks amplify the issues of generally poor soil quality and low soil organic matter (SOM) in Mediterranean agricultural systems. Soil degradation is exacerbated by harsh climatic conditions, low vegetation cover, and intensive agricultural practices. Together, these processes result in increasing uncertainties regarding agricultural incomes and food security on a regional and local scale (Aguilera et al., 2013; Ferreira et al., 2022; Skuras & Psaltopoulos, 2012). Some Mediterranean regions may completely lose their suitability for cultivation of specific crops (Ceglar et al., 2019).

One prominent land management strategy for soil conservation is conservation agriculture (CA), a farming practice relying on three core principles: (i) minimum mechanical soil disturbance, (ii) permanent cover of crop residues remaining on the fields after harvest, and (iii) species diversification through crop rotations and other practices (FAO, 2016; Kassam et al., 2012). Implementing these principles requires a paradigm shift from a tillage and monoculture-based farming system, in which crop residues are generally removed from the fields, to a no-till and diversified system with permanent soil cover that aims at promoting sustainable production intensification (Kassam et al., 2020). While many studies have demonstrated economic, agronomic, and environmental benefits of CA over conventional tillage (Kassam et al., 2009; Lee et al., 2019; Vastola et al., 2017), there is debate about its efficacy in aspects such as improving crop productivity in humid regions (Pittelkow et al., 2015a) and its contribution to soil carbon sequestration (Powlson et al., 2014).

Although CA has become a widely adopted farming practice in some parts of the world, its adoption in the Mediterranean region remains low, despite agreement in the literature that CA offers Mediterranean farmers the chance to increase their resilience and productivity in the face of changing climatic conditions (Kassam et al., 2012; Lagacherie et al., 2018). For instance, reduced or no-tillage approaches in combination with cover crops has been shown to be an effective strategy for increasing organic carbon in Mediterranean soils (Aguilera et al., 2013). Cover crop management was found to have a positive impact on increasing soil water storage and decreasing water run-off, thereby reducing soil erosion (Lee et al., 2019). A global meta-analysis by Pittelkow et al. (2015b) revealed that, under rainfed crop systems in dry climates, yields could be increased by 7.3% relative to those of conventional tillage systems is possible when all three CA principles were implemented.

Several factors have influenced the limited adoption of CA in the Mediterranean region. Well-known challenges include a lack of knowledge, unavailability of machinery, high input costs, unfavourable policies, and increased labour demand, as well as socio-economic constraints (Kassam et al., 2020; Lahmar, 2010; Mrabet et al., 2022). For instance, Fouzai et al. (2018) found that level of education and land ownership (as opposed to leasing) were positively correlated with the adoption of CA in a Tunisian region prone to soil erosion. Economic interests also played a decisive role in Spanish olive growers' choice of soil management practices (Aznar-Sánchez et al., 2020; Sastre et al., 2017).

Sociocultural constraints to CA adoption have been investigated less, but can also be influential. For example, the way in which farmers perceive soil management has an influence on their understanding and decision-making. These perceptions and expectations can inform adoption of CA even more than concrete realities (Pannell et al., 2014). A study by Prager and Curfs (2016) revealed that olive growers in southwestern Spain do not perceive soil tillage as being a soil management practice. Instead, they perceive tillage as a tool for controlling the spread of woody shrubs, eliminating competition for nutrients and water by weeds, and maintaining tidiness in their olive orchards. Consequently, the objective of reducing soil degradation through the principle of tillage reduction cannot be expected to be inherently aligned with farmers' realities, as they may either lack understanding of how tillage affects soil attributes, or not believe that tillage can harm soils. Rather, soil degradation may appear to farmers as an undesirable natural side effect that they are powerless to counteract (Ingram et al., 2010).

Conservation agriculture practices may also be rejected by farmers because they do not produce some commonly acknowledged symbols of 'good farming' that have contributed to the formation of farmers' identities (Burton et al., 2008; Burton & Paragahawewa, 2011; McGuire et al., 2013; Raedeke et al., 2003). Each style of farming has its own specific criteria upon which the farmer assesses his or her relative success or failure (van der Ploeg, 2022). Intensive tillage is a central feature of agricultural management in the Mediterranean, where traditional and smallholder farming is still the norm (Lee et al., 2019; Mrabet et al., 2022). For these communities, the plough symbolizes tradition and has sustained yields for centuries (Friedrich & Kassam, 2009). These symbols often align with productivist values, such as maintaining a tidy farm appearance through straight-lined and weed-free crops (Burton, 2004; Burton et al., 2008). Thus, farmers may feel that reducing tillage under CA may lead to them being judged as untidy, incompetent, or inefficient (Burton & Paragahawewa, 2011). Such symbols are not static, but rather prone to change; it has been observed that farmers are increasingly embracing soil stewardship and other dimensions of sustainability (Burton et al., 2021; McGuire et al., 2013; Sutherland & Darnhofer, 2012; Westerink et al., 2021). For instance, a recent study in the U.S.A. revealed that soil erosion was evaluated by wheat farmers as evidence of insufficient skills and inefficient farm management (Lavoie & Wardropper, 2021).

The conceptualization of the 'good farmer' identity is grounded in Bourdieu's framework of field, habitus, and capital (Bourdieu, 1984; Burton et al., 2021; Burton & Paragahawewa, 2011). The good farmer literature has largely focused on the relevance of cultural capital in shaping identities (Burton & Paragahawewa, 2011). Embodied cultural capital is related to the performance and demonstration of everyday farming activities and skills, and may result in the reward of other forms of capital, such as social capital through increased status of the farmer within his/her farming community (Burton et al., 2008). Beyond material wealth and financial security, the goals of farmers typically also encompass social approval and acceptance, including being recognized for farming well (Pannell et al., 2006).

To fill the current research gap on the sociocultural barriers to the uptake of more sustainable forms of agriculture, the overall aim of this study is to elicit mental models of 'good soil management' and the 'good farmer' identity among farmers practicing either CA or conventional agriculture in contrasting parts of the Mediterranean region. Mental models are defined as an individual's or group's internal representation of the external world; they serve as a reflection of how individuals or groups of individuals perceive and understand the world around them (Lynam & Brown, 2012). Jones et al. (2011) describe mental models as the basis of reasoning, decision-making, and behaviour upon which new information is filtered and stored. The elicitation of mental models can be found in many agricultural science studies as a method to capture farmers' perceptions, decision-making processes, or understanding towards the adoption of sustainable farming practices (Halbrendt et al., 2014; Hoffman et al., 2014; Lalani et al., 2021; Prager & Curfs, 2016). The specific objectives of this study are to:

1. identify the core concepts involved in the understanding of 'good soil management' practices among Mediterranean farmers,
2. reveal the key components of Mediterranean farmers' understanding of what constitutes a 'good farmer' and
3. determine whether farmers' understandings differ according to their tillage practices (minimum/no-tillage vs. conventional tillage).

Our central hypothesis is that farmers with differing agricultural practices may have different mental models of what constitutes a 'good farmer'. Eliciting farmers' mental models may reveal how their perceptions allow or impede the adoption of CA, and how incentives, policy regulations, and measures for extension in the Mediterranean region could be designed to include farmers' mental, cultural, and contextual realities.

2. Material and methods

2.1. Study regions

This study took place in cereal-producing regions of Morocco, Spain, and Tunisia (see Figure 1), where mixes of both CA and conventional agriculture are practiced. All regions have limited irrigation, meaning that the majority of crop production is dependent on rainfall. In Morocco, the study was conducted in the Meknes, Oued Zem, and Settat districts. In Meknes, the average annual rainfall is

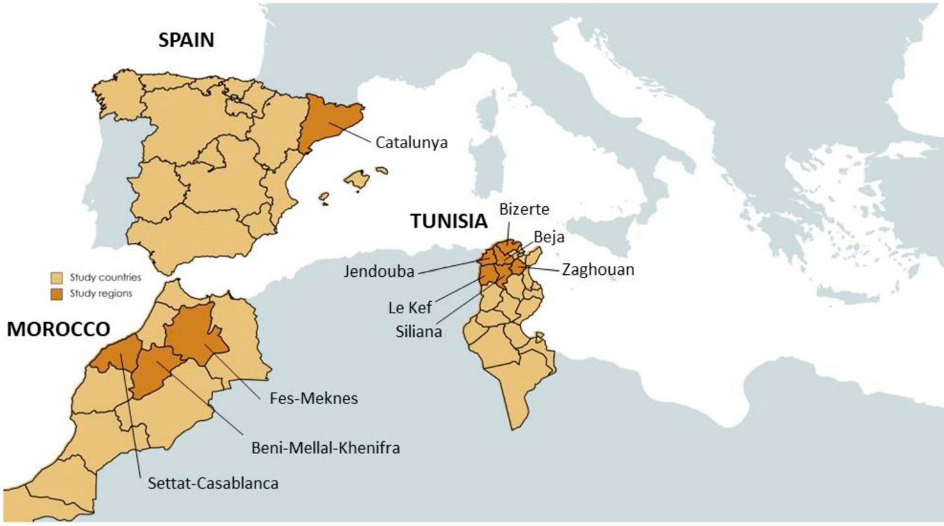


Figure 1. Countries and case study regions of this study.

approximately 400–600 mm, whereas in the semi-arid areas of Oued Zem and Settat, the average rainfall is less than 400 mm per year. Farmers in these areas produce mostly wheat, durum wheat, barley, and forage crops, as well as some vegetables and olives. Small ruminant livestock are also a key part of the production systems in Morocco. Farmers mainly practice conventional agriculture, in which inversion tillage is a key practice. However, an estimated 10,500 hectares of farmland are cultivated under CA (Kassam et al., 2020; Mrabet et al., 2022). These farmers are typically directly seeding crops onto residues and using pesticides for weed control, while integrating crop rotations that include legumes.

In Spain, the study was conducted in the region of Catalonia, in the districts of El Vallès, La Noguera, La Segarra, Alt Urgell, and La Cerdanya. These regions span a rainfall gradient of approximately 500–700 mm per year. The main crops are wheat, barley, oats, and forage crops, with some vegetable and fruit production. Some farmers are also engaged in pork, poultry, and cattle production and their cereal production is mostly destined for feed. Organic farming is a key part of the agricultural sector in Catalonia. Approximately 10–15% of farmers are following CA practices. Organic CA farmers, often perform direct seeding on residues, using some strategic tillage or a chemical-free approach to weed control. Non-organic CA farmers typically directly seed crops onto residues and use pesticides for weed control. Most farmers have diverse crop rotations that include legumes.

In Tunisia, the study was conducted in the semi-arid areas of Zaghouan, Siliana, Jendouba, and Kef, where the average annual rainfall is less than 400 mm, and the sub-humid areas of Bizerte and Béjà, which receive approximately 400–600 mm per year. The main crops are wheat, durum wheat, and barley, along with extensive olive production. Small ruminant livestock are also a key part of the system. The majority of farmers in Tunisia practice conventional agriculture with inversion tillage. Only 150–200 farmers are estimated to be practicing CA; they typically directly seed crops onto residues and use pesticides for weed control, while integrating crop rotations that include legumes. Organic farming is not common for cereal production in Tunisia, but olive plantations are typically managed without mineral fertilizers or pesticides. However, these plantations are not normally certified under organic certification schemes.

2.2. Survey development and data collection

We developed a questionnaire to investigate perceptions and beliefs relating to soil management and CA among farmers. The questionnaire comprised a mix of 34 open and closed questions. The data presented in this paper was derived from two open questions in section two of the survey: (1) Can you give a short definition of what 'good soil management' means to you? and (2) Can you describe what, in your opinion, makes a 'good farmer'? These questions were open-ended with no suggested answers and no limit on the length of the answer. The questionnaire was translated into local languages of French, Arabic, and Catalan.

Data were collected by regional project partners using the questionnaire to survey farmers between May 2021 and January 2022. Farmers were initially targeted in each country through existing extension networks and through lists of farmers who had previously participated in research and development projects with project partners. Farmers either participated in the survey while attending training workshops or were visited by researchers at their farms. Neighbouring farmers to those initially contacted were also visited and invited to participate, until a balance was reached between farmers practicing CA and those practicing conventional agriculture in each country. All participants gave their free, prior, and informed consent before participating in the survey. Prior to beginning the study, we conducted an ethics self-assessment from the University of Kassel and were recommended to take an ethically sensitive approach with adherence to scientific standards. Participating farmers were surveyed individually, either face-to-face or were provided with a printed version of the survey. Due to local regulations relating to the Covid-19 pandemic in Spain, farmers and researchers could not meet face-to-face, so an online version of the survey was created using LimeSurvey software. The survey was active between September 2021 and January 2022. A link to this survey was sent to farmers that were contacted previously via email or telephone by the research partners.

Survey responses were collected, entered into spreadsheets, cleaned and checked for clarity, and translated into English. Responses were then collated into a central spreadsheet for analysis. In total, 592 farmers participated in the survey. After cleaning and translating, a total of 590 samples were available for analysis. The sample comprised 33.9% Spanish, 33.6% Moroccan, and 32.5% Tunisian farmers. Farmers were grouped according to whether they followed minimum or no tillage (i.e. CA) or conventional tillage practices. In total, 271 farmers (45.9%) were practicing conventional tillage and 319 farmers (54.1%) were practicing CA.

2.3. Data analysis

Mental models may be conceptualized as concept networks consisting of nodes representing concrete concepts and ties illustrating non-directional associations among different concepts (Carley & Palmquist, 1992; Hoffman et al., 2014). Our data analysis took place in six steps (see Figure 2). First, we extracted concepts from farmers' open responses through an exploratory coding process, where in concepts emerged directly from the content of the responses as codes without a pre-existing framework (Carley & Palmquist, 1992; Hoffman et al., 2014). We then performed iterative coding with MAXQDA 22.2.0. following the main principles for performing a structuring qualitative data analysis on a data-driven basis, i.e. based on the content of the responses itself (Mayring, 2014; Rädiker & Kuckartz, 2020). The coding system was developed through three iterative rounds, until no new codes were identified among the responses. We performed this process for the responses to both questions, i.e. for perceptions of 'good soil management' and the 'good farmer' identity.

Second, we tested the coding system for reliability using the Intercoder Agreement tool in MAXQDA, as proposed by Kuckartz and Rädiker (2019). We randomly selected 10% of cases and assigned them to be coded separately by two researchers. The average percentage agreement was 64.1% for 'good soil management' and 66.7% for 'good farmer' identity. Thresholds for intercoder agreement are not defined by Rädiker and Kuckartz (2020) but practical improvements of the coding system are made through discussions on non-agreements. The adjustments discussed included the addition, renaming, merging, and deletion of codes.

Third, for revealing associations among different concepts, we followed the approach described by Hoffman et al. (2014), who define associations between concepts as 'co-occurrence of two given concepts in a single definition' (Hoffman et al., 2014, p. 13020). We created symmetrical adjacency matrices with the MAXQDA tool 'Code-Relations-Browser'. Adjacency matrices are basic mathematical structures for expressing networks (Hanneman & Riddle, 2011a). This tool offers the possibility to analyse and visualize relationships between codes by displaying which codes co-occur and how often within a response.

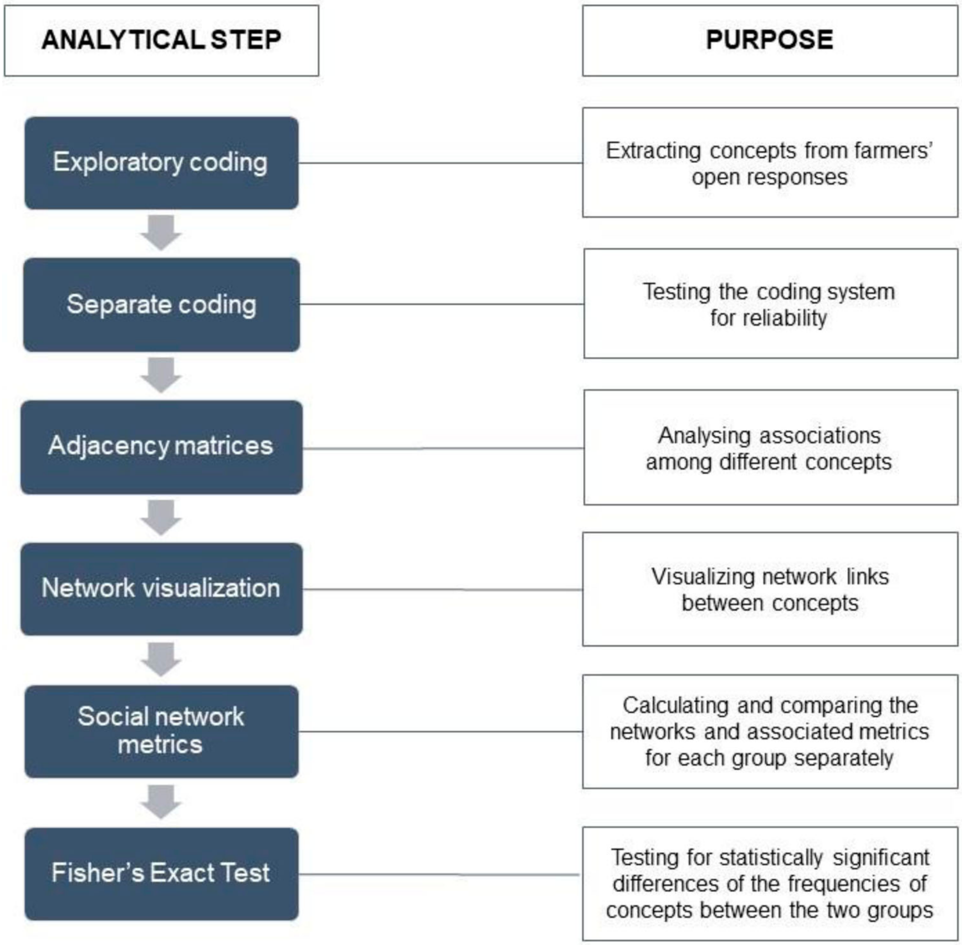


Figure 2. Analytical steps performed for the mental model analyses.

Fourth, we visualized the networks using the Force Atlas 2 layout in Gephi, a free and open-source network analysis and visualization software package.

Fifth, we calculated social network metrics, using Microsoft Excel and Gephi. Social network metrics enable the description of a network from both top-down and bottom-up perspectives. This permits an overview of the network as a whole, further providing insights into the way single nodes are embedded within the network (Hanneman & Riddle, 2011b). We calculated: (i) network size; (ii) total number of ties (also called edges); (iii) density; (iv) average degree and average weighted degree (Hanneman & Riddle, 2011b); (v) occurrence probability; (vi) eigenvector centrality; and (vii) prominence of each concept (Hoffman et al., 2014), for both 'good soil management' and 'good farmer' identity. The size of the network is determined as the total number of nodes and indicates the total number of concepts mentioned by the farmers. The total number of edges indicates the number of ties existing between the concepts. Density is a metric ranging from zero to one that indicates the proportion of realized edges out of all possible edges (Arif, 2015). The lower the density value, the less connected the nodes are in the network. The average degree is the average number of edges per node, and the average weighted degree is the average sum of weights per node in a network (Hanneman & Riddle, 2011b). Occurrence probability is calculated as the ratio of statements that included a given concept to total number of responses in the sample. Eigenvector centrality is a measure for calculating the influence of a node within the network based on its connections to other nodes (Wei et al., 2011). In contrast to other centrality measures, it does not consider all edges as equal, and instead depends on the number as well as the quality of a node's connections (Newman, 2008). Prominence is a measure proposed by Hoffman et al. (2014) for indicating a concept's influence and is obtained by calculating the mean of occurrence probability and eigenvector centrality. This measure can be ranked to depict which concepts are most widely acknowledged among farmers and cognitively associated with other important concepts.

Finally, to investigate whether the two tillage practice groups differed in their concept networks of 'good soil management' and 'good farmer' identity, we calculated the networks and associated metrics for each group separately and then compared them, both visually and quantitatively. We tested for statistically significant differences of the frequencies of concepts between the two groups using Fisher's exact test. This test is commonly recommended instead of the Chi-square test if expected frequencies of some cells of the contingency table are less than five (Bower, 2003).

For the subsequent Results section, these analytical steps were condensed into concept network visualizations and associated metrics of 'good soil management' for all farmers, and then split between those practicing minimum and no tillage and those tilling conventionally. The same method was followed for the data on 'good farmer' identity. For simplicity, we focused on the ten most-prominent concepts for each network, but additional information on each network is included in the Appendices. Verbatim extracts from the coded responses were used to illustrate the concepts.

3. Results

3.1. Understanding of good soil management

3.1.1. All farmers

Overall, 55 concepts related to good soil management were elicited from all farmers' responses (Figure 1, Appendix 1). A total of 418 reciprocal links between concepts were identified in the network. The average degree was 15.20 and the average weighted degree was 39.89. The network had a density of 0.281. The size of the nodes is proportional to prominence values. As shown by the width of the linkages, the co-occurrence of mineral fertilizers/tillage was the most frequently mentioned (55 mentions), followed by mineral fertilizers/crop rotation (30 mentions).

The ten most relevant concepts based on prominence values are displayed in Table 1. Crop rotation was identified as the most prominent concept (prominence 0.594), followed by mineral fertilizers (0.580) and tillage (0.589). CA management practices and objectives such as crop rotation, soil conservation and improvement, soil fertility and organic matter, reduced tillage and no-tillage, and soil structure were central concepts.

3.1.2. Difference between farmers practising conventional and minimum & no-tillage

The 'good soil management' networks of farmers practicing CA and those practicing conventional tillage were similar in terms of size, with 51 and 50 concepts, respectively, but differed in network complexity (Figure 2). The CA network comprised more edges (293 vs. 229), a higher average degree (11.49 vs. 9.16) and a higher average weighted degree (23.73 vs. 19.68). Thus, more links were created between concepts by CA farmers, which is also indicated by the higher density value of the network when compared to that of the conventional tillage network (0.230 vs. 0.187). A significant difference between the two groups was found for frequencies of concepts (Fisher's test, $p < 0.05$).

While 'Organic and natural fertilisers', 'Productivity', 'Soil conservation and improvement', and 'Reduced and no agrochemicals' were central in both mental models (see Table 2), CA concepts were common and central in the mental model of CA farmers. 'Crop rotation' was the most prominent concept, followed by 'Soil fertility and organic matter', 'Soil conservation and improvement', 'Soil structure' and 'Reduced and no-tillage' for the CA farmers (Table 2). For example, some farmers mentioned that good soil management means 'doing a good crop rotation' (S112), 'improving soil structure in quantity and quality' (T15), or 'applying zero labour' (M75), the latter meaning avoiding tillage. However, permanent soil cover, while a central practice in CA, was less prominent in the network. Further central concepts of the network were related to crop productivity aspects ('farming practices that provide high yields' [T94]) and external farm inputs. Furthermore, some farmers mentioned that good soil management means reducing pesticides, for example to protect soil microfauna: 'It is necessary to completely avoid the use of pesticides that can negatively affect microbial communities and soil fauna' (S43).

Table 1. Top ten concepts in overall concept network of good soil management.

Concepts	Occurrence probability	Eigenvector centrality	Prominence	Examples of good soil management
1. Crop rotation	0.188	1.0000	0.594	'rotate well' (S94), 'crop rotation' (M41), 'rotation is compulsory' (T31)
2. Mineral fertilizers	0.237	0.941	0.590	'add fertilisers frequently' (S41), 'application of fertilisers' (M53), 'give fertiliser to the soil' (T48)
3. Tillage	0.223	0.954	0.589	'till the soil' (S70), 'clean it of herbs with the plough' (M23), 'ploughing' (T14)
4. Soil conservation and improvement	0.117	0.868	0.493	'not destroying living soil' (S38), 'soil conservation' (M108), 'improve soil quality' (T83)
5. Organic and natural fertilizers	0.107	0.877	0.492	'apply green manure' (S123), 'organic fertilisers' (M9), 'organic fertilisers instead of chemical' (T2)
6. Productivity	0.108	0.854	0.481	'obtain good productions' (S22), 'provide high yields' (T94)
7. Soil fertility and organic matter	0.090	0.829	0.459	'improving fertility' (S37), 'increase percentage of organic matter' (M135), 'conservation of soil fertility' (T61)
8. Reduced and no-tillage	0.095	0.800	0.447	'touch the ground as little as possible' (S15), 'practice zero tilling' (M62), 'for soil conservation we must minimise tillage' (T31)
9. Soil structure	0.037	0.788	0.413	do not compact' (S102), 'soil that retains water' (T29)
10. Best management practices	0.063	0.741	0.402	'do the right and necessary practices' (S140), 'use instructed dosages' (M8), 'application of the technical package' (T129)

Note: Codes in brackets refer to the country (S, Spain; M, Morocco; T, Tunisia) and respondent ID.

'Tillage' was the most prominent concept in the conventional farmers' mental model with a prominence value of 0.728 (Table 2). These farmers frequently mentioned that tilling or ploughing is an important contribution to their soil management for controlling weeds, providing adequate production conditions, or aerating the soil. 'Applying mineral fertilisers' and adopting 'Crop rotation' were also highly central aspects for conventional tillage farmers. Performing practices at the right time was often linked with good soil management by conventional tillage farmers. For example, many farmers mentioned that it is important to 'work at the right time' (S184) and to respect the 'agricultural calendar' (M99) when sowing, harvesting, or applying agrochemical treatments. In contrast to the minimum tillage farmers, the conventional tillage farmers frequently addressed the application of herbicides as an important feature in order 'to clean the land' (M134).

3.2. Understanding of 'good farmer' identity

3.2.1. All farmers

Overall, 64 concepts of 'good farmer' identity emerged from the responses (Figure 3, Appendix 2). Overall, 407 edges were identified in the network. The average degree was 12.72, the average weighted degree was 62.10, and the network density was 0.202. Particularly strong ties were observed between the concepts of 'Productivity', 'Profitability',

Table 2. Top ten concepts in the 'good soil management' concept networks for both tillage groups. Frequency refers to the number of farmers that mentioned the concept. For simplicity, only the prominence value is reported here.

Conservation Agriculture (CA) (319)				Conventional tillage (271)			
Concept	Frequency	%	Prominence	Concept	Frequency	%	Prominence
1. Crop rotation	66	20.7	0.603	1. Tillage	99	36.5	0.728
2. Soil fertility and organic matter	35	11.0	0.549	2. Mineral fertilizers	75	27.7	0.630
3. Soil conservation and improvement	41	12.9	0.534	3. Crop rotation	45	16.6	0.559
4. Soil structure	19	6.0	0.529	4. Organic and natural fertilizers	43	15.9	0.498
5. Reduced and no-till	51	16.0	0.507	5. Productivity	29	10.7	0.399
6. Productivity	35	11.0	0.481	6. Soil conservation and improvement	28	10.3	0.388
7. Mineral fertilizers	65	20.4	0.476	7. Agrochemicals	23	8.5	0.376
8. Soil cover	17	5.3	0.439	8. Right timing	15	5.5	0.335
9. Organic and natural fertilizers	20	6.3	0.421	9. Reduced and no agrochemicals	10	3.7	0.323
10. Reduced and no agrochemicals	15	4.7	0.417	10. Clean fields	19	7.0	0.316

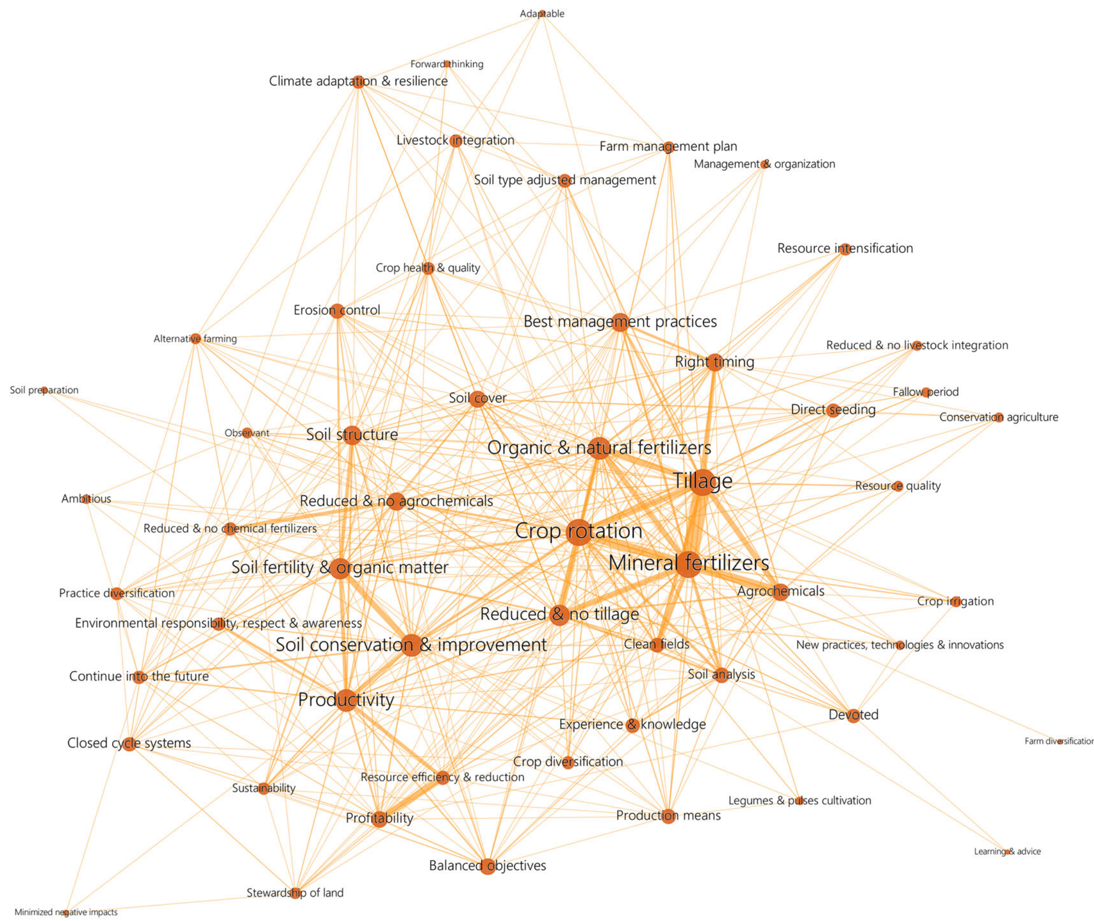


Figure 3. Overall mental model of 'good soil management' for all farmers. Size of node indicates prominence value of concept.

'Environmental responsibility', 'Respect and awareness', and the practices of 'Tillage', 'Fertilisers', 'Crop rotation', and 'Agrochemicals'.

The key concepts of the overall mental model are presented in Table 3. 'Productivity' was the most central concept, and refers to obtaining high yields and good crop productivity. The next most prominent concepts reflected farmer characteristics, such as 'Experience and knowledge' and being 'Observant'. These concepts were illustrated by statements that a good farmer is someone who 'has experience and competence' (T71) in his profession and who 'keeps a watchful eye' (M173) on his crop and farm. Being open to 'new practices, technologies, and innovations' and having the willingness to learn were generally considered important characteristics of a farmer. Furthermore, it was generally believed that a good farmer must to ensure his farm is economically profitable. Beyond farmer characteristics, aspects of farm and soil management were also central, with mineral fertilizers and tillage frequently mentioned, similarly to in the good soil management network. A good farmer was seen to be one that 'works the soil well' (S21) and 'intensifies fertilisers' (M68).

3.2.2. Differences between farmers practising conventional tillage and CA

The concept networks for 'good farmer' identity were similar for CA and conventional tillage farmers in terms of size and structure, with 60 and 56 concepts, respectively (Figure 4). The CA network comprised more edges (287 vs. 220), a higher average degree (9.57 vs. 7.86), a higher average weighted degree (17.17 vs. 17.14), and a slightly higher density (0.162 vs. 0.143) than that for conventional farmers. A significant difference was found between the two groups in terms of frequencies of concepts (Fisher's test, $p < 0.05$).

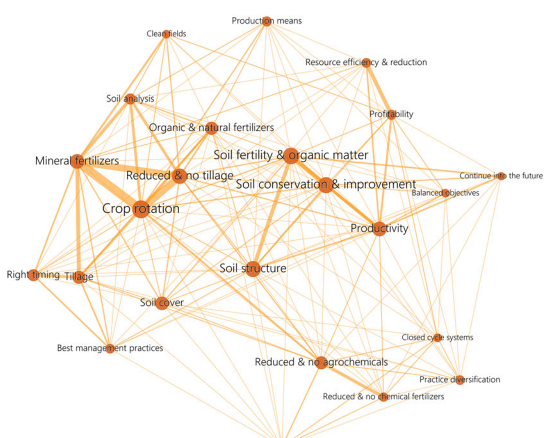
Table 3. Top ten concepts in overall concept network of 'good farmer' identity.

Concept	Occurrence probability	Eigenvector centrality	Prominence	Examples of good farmer identity
1. Productivity	0.169	1.000	0.584	'obtains great production' (S13), 'realizing yields' (M72), 'high yields' (T161)
2. Experience and knowledge	0.129	0.895	0.512	'the experience and expertise of the farmer' (S1), 'has experience and competence' (T71)
3. Observant	0.044	0.888	0.466	'good observer' (S81), 'keeps a watchful eye on his farm' (M173), 'well supervised farm' (T106)
4. New practices, technologies and innovations	0.058	0.829	0.443	'apply new technologies and techniques' (S15), 'follows new trends and innovations' (M160), 'accepts change' (T123)
5. Profitability	0.072	0.800	0.436	'live from what you produce' (S64), 'achieves high return' (M56), 'chooses the most profitable crops' (T7)
6. Right timing	0.072	0.766	0.419	'knows when is the best time to plant' (S138), 'tilling in right time' (M30), 'applies the right techniques at the right time' (T22)
7. Stewardship of land	0.049	0.767	0.408	'takes care of the soil and land' (S4), 'keeps a watchful eye on the land' (M153), 'preserves his land' (T139)
8. Learning and advice	0.061	0.746	0.404	'must have concerns to learn' (S43), 'asks for help and advice' (M167), 'seeks information' (T96)
9. Tillage	0.123	0.681	0.402	'works the soil well' (S21), 'tilling in time and many times' (M22), 'works the land' (T60)
10. Mineral fertilizers	0.116	0.677	0.396	'intensifies fertilisers' (M68), 'treatments' (T73)

Achieving high yields and good crop performances was widely associated with being a good farmer by CA farmers, with 'Productivity' having the highest prominence value (Table 4). Concepts such as 'New practices, technologies and innovation' and spanned until the eight position in the ranking with devoted. Lastly, having good 'Profits' and adopting 'Crop rotation' were widely recognized among CA farmers as dimensions of being a good farmer (Figure 5).

'Tillage' was identified as a core concept in the mental model of conventional tillage farmers followed by 'Experience and knowledge' and 'Productivity', the latter two taking sinmialr importance in the mental model of CA farmers. Mineral fertilizers also ranked prominently, as conventional tillage farmers widely consider mineral fertilizers as being good for their land ('takes good care of his land by […] using fertilisers' [M148]). According to most conventional tillage farmers, keeping the 'Right timing' for agricultural practices (tillage, sowing, etc.), as well as having weed-free and 'Clean fields' were perceived as being traits of a good farmer.

The mental models of good farmer identity for CA and conventional tillage farmers are presented in Figure 6.



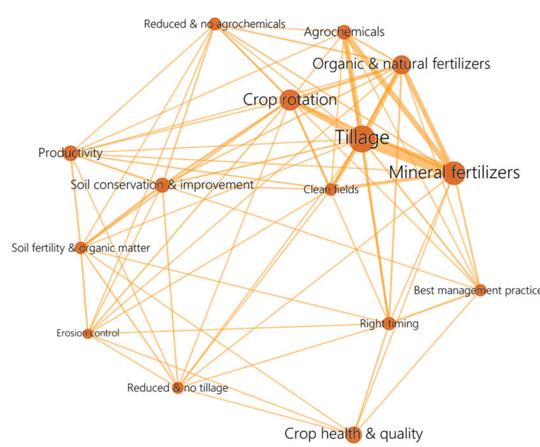


Figure 4. Mental models of good soil management for CA (left) and conventional tillage (right) farmers, indicating the most prominent concepts. Size of node indicates prominence value of concept.

Table 4. Top ten concepts in 'good farmer' concept network for both tillage groups. Frequency refers to the number of farmers that mentioned the concept. For simplicity only the prominence value is reported here.

Conservation Agriculture (CA) (319)				Conventional tillage (271)			
Concept	Frequency	%	Prominence	Concept	Frequency	%	Prominence
1. Productivity	57	17.9	0.590	1. Tillage	65	24.0	0.620
2. New practices, technologies, and innovations	24	7.5	0.507	2. Experience and knowledge	35	12.9	0.540
3. Experience and knowledge	41	12.9	0.437	3. Productivity	42	15.5	0.521
4. Learning and advice	23	7.2	0.427	4. Mineral fertilizers	44	16.2	0.507
5. Environmental responsibility, respect and awareness	30	9.4	0.424	5. Right timing	24	8.9	0.481
6. Observant	16	5.0	0.397	6. Observant	10	3.7	0.453
7. Rational	11	3.4	0.394	7. Best management practices	23	8.5	0.417
8. Devoted	24	7.5	0.366	8. Clean fields	15	5.5	0.406
9. Profitability	26	8.2	0.323	9. Production means	30	11.1	0.389
10. Crop rotation	26	8.2	0.318	10. Profitability	16	5.9	0.387

4. Discussion

This study set out to identify key concepts of 'good soil management' and 'good farmer' identity that are incorporated in Mediterranean farmers' understanding of soil management and their decision-making processes in respect thereof. Our working hypothesis was that farmers who engaged in differing agricultural practices would also hold different mental models. While some core concepts were common to all farmers, our hypothesis was confirmed through differences identified between the mental models of farmers practising CA and of those applying conventional tillage. Here, we first discuss farmers' understanding of good soil management, considering the diverging mental models among CA and conventional farmers. We then discuss the different types of capital shaping farmers' understanding of what it means to be a 'good farmer', also considering diverging mental models. Last, we reflect on the study design and present conclusions.

4.1. Good soil management

Regarding our objective of identifying the core concepts concerning good soil management among Mediterranean farmers, we found that 'Crop rotation' was the most central concept in mental models of good soil management. Other studies identified similar perceptions among agricultural stakeholders. For example, Di Bene et al. (2022) revealed that crop rotation was perceived as one of the most important adaptation strategies in Mediterranean cereal-based cropping systems. Farmers perceived crop rotation as the most adequate strategy for diversifying intensive cereal production, in comparison to other strategies such as intercropping. However, crop rotations approaches can vary widely, from simple two-crop systems to diversified systems involving three or more crops. The latter is preferred by proponents of CA (Bowles et al., 2020; FAO, 2016). Diversified crop rotations that also include legumes were found to be more efficient and sustainable in Mediterranean cropping systems (Christiansen et al., 2015). We found that few farmers mentioned forage legume and pulse cultivation directly, although this may be implicit in their mentions of 'Crop rotation'. An absence of legume cultivation or experimentation with different crop types may be due to a lack of knowledge about newly introduced crops, increasing costs for additional machinery, and uncertainties regarding the profitability of new crops (Vanino et al., 2022; Wang et al., 2021).

Our results suggest that while wheat and barley monoculture is prevailing in today's Mediterranean cropping systems, crop rotation is largely accepted as a solution to issues such as poor long-term soil nutrient balance and low yields (Bouatrous et al., 2022). The concept network shows 'Crop rotation' as a bridging concept tied to both tillage and reduced/no-tillage practices, highlighting how this practice can be implemented by both types of farmers. The practice of crop rotation is thus an important entry point for engaging conventional farmers' consideration of CA practices, as it does not contradict their mental reality surrounding soil management decisions. Additionally, it does not require the break

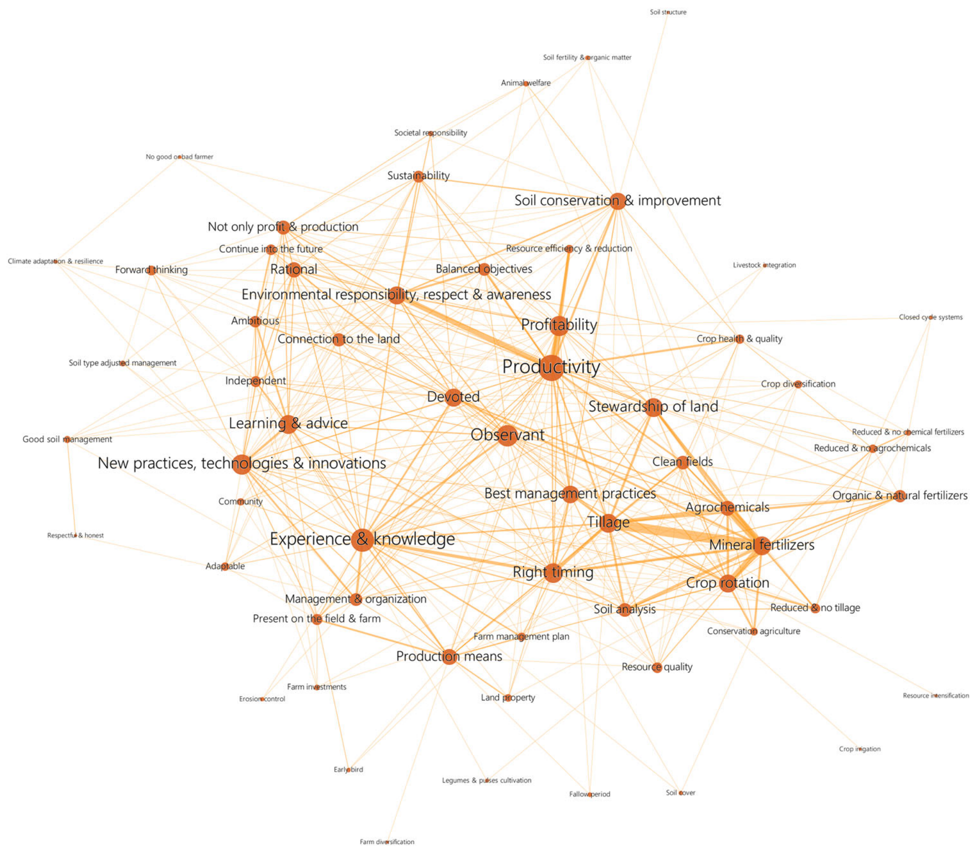


Figure 5. Overall mental model of 'good farmer' identity for all farmers. Size of node indicates prominence value of concept.

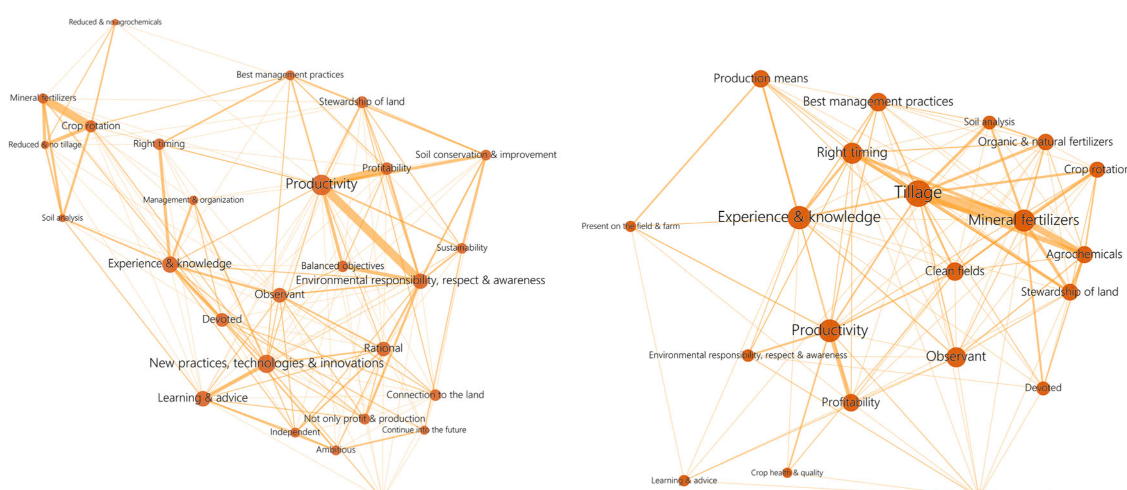


Figure 6. Mental models of 'good farmer 'identity for CA (left) and conventional tillage (right) farmers indicating most prominent concepts. Size of node indicates prominence value of concept.

from traditional tillage and the associated capital that are required for reduced tillage practices.

In line with our central hypothesis, several differences were found between conventional and CA farmers. For instance, conventional farmers considered 'Tillage' alongside 'Fertilisation' as central soil management practices. This perception contrasts scientific evidence that repetitive tillage has negative impacts on long-term soil functions and properties in the Mediterranean (Cerdà et al., 2020). However, farmers practice tillage for multiple reasons, such as eliminating weeds and reducing potential fire fuel loads (Prager & Curfs, 2016). Furthermore, although intensive application of nitrogen fertilizers leads to increased greenhouse gas emissions from soil due to nitrification and denitrification processes (Aguilera et al., 2013b), both organic and mineral fertilizer applications are widespread in the Mediterranean region, and are used to maintain stable yields in soils low in organic matter content (Ryan et al., 2009). A somewhat unexpected result was the secondary role played by 'Productivity' in the mental model for conventional farmers, which appeared with a much lower prominence than the above mentioned central concepts. Interestingly, permanent soil cover was not as important as other CA practices in the CA concept network, likely due to issues with grazing residues in these regions as well as the lack of water and seeds available for cover crops (Cicek et al., 2023). Promoting CA practices in the Mediterranean requires that these motivations be addressed, considering regional differences. The results suggest the use of particular management approaches for targeting soil conservation, as exemplified by the strong connection of tillage and mineral fertilizer in conventional farmers' mental model. Alternative fertilization strategies should be promoted to combat soil and environmental issues associated with excessive fertilizer use.

Certain concepts appeared in CA farmers' understandings of 'good soil management' but not in those of conventional farmers. These concepts included soil structure, fertility, conservation, and improvement, suggesting that CA farmers are more aware of soil issues and relate this to their crop production. The understanding of good soil management was overall more complex among CA farmers, indicated by more concepts and ties and absence of a prominent central concept/linkage, which did exist for conventional farmers. These results align with the findings of Lalani et al. (2021), who highlighted that farmers who practice or have practiced CA think systemically about causal relationships among environmental conditions, farming practices, and agricultural outcomes, as compared to the more linear thinking of conventional farmers. Enhancing farmers' understanding of the links between soil function and productivity should therefore be foundational in outreach programmes for CA adoption. Interestingly, climate adaptation and resilience were rarely mentioned by farmers, despite the serious threat this poses for Mediterranean agriculture. Finally, another surprising result was the link between key components of CA (no tillage and crop rotation) with mineral fertilizers, which we might have hypothesized to emerge as a secondary concept unrelated to the former. However, mineral fertilizer is closely linked to these CA concepts because it may in fact be part of the CA approach in some areas, being widely promoted for example in Morocco, and is therefore at the forefront of many farmers' minds with regards to improving their soil.

4.2. 'Good farmer' identity

Concerning the second objective of revealing the key components of Mediterranean farmers' understanding of the 'good farmer' identity, the concepts 'Productivity' and 'Experience and knowledge' were most prominent in the overall mental model, but were also among the most prominent in the separate mental models of both conventional and CA farmers. Therefore, these concepts are seen as indicators of good farming practices by Mediterranean farmers regardless of their adopted tillage practices.

The most prominent and central concept for the overall sample was 'Productivity'. This finding echoes other studies that identified productivist values as dominating farmers' identities (Burton, 2004; McGuire et al., 2015; Saunders, 2016). This concept is also closely linked to the economic viability of their farms, as the possibility for accumulation of economic capital rises with increased turnover. Obtaining high yields is the result of a farmer's competence and allows him/her to invest in his/her farm and to 'make a living from his work' (S90), as some farmers of the survey stated. Farmers of both groups linked productivity to profitability, demonstrating the importance of economic capital and agricultural output for farmers.

While economic success is one of the main drivers in farmers' decision making (Sardaro et al., 2021; Wittstock et al., 2022), it is accompanied by the urge to demonstrate their farming skills through further symbols of good farming. Accordingly, the next most prominent concept was 'Experience and knowledge', which also occupied a central position for both conventional and CA farmers separately. This quality demonstrates competence in farming activities, being a way for farmers to gain cultural capital and form a 'good farmer' identity (Burton et al., 2008).

The prominence of the concept of 'Tillage' as a concept for conventional farmers demonstrates the importance of the plough and of tilling as a skilled activity, and suggest that for conventional farmers, a 'good farmer' is one that implements a set of accepted best management practices. Additionally, tillage is key to having 'Clean fields', which are seen as visible outcomes of farming efficiency and skill (Burton, 2004; Schmitzberger et al., 2005). These symbols of good farming are also related to the economic efficiency of the farm, as, for instance, evenly ploughed fields ensure regular sowing depths which results in evenly emerging plants, and parallel lines ensure that pesticides and herbicides are evenly dispensed within the crops (Burton et al., 2008). The finding that this concept forms part of Mediterranean farmers' identities suggests that social norms may influence farmers' practices and aligns with the idea of 'roadside farming', which describes farmers' judgement of other farmers' skill and success based how their farmland looks from the roadside (Burton, 2004). Farmers may opt out of alternative or beneficial practices when they feel these challenge the community status quo (Rust et al., 2023). 'Experience and knowledge' and 'Productivity' followed in importance to 'Tillage'. These three concepts emerged as separate nodes with loose interrelations among them, indicating the complexity underpinning identity constructs.

CA farmers and conventional farmers both perceived the high importance of 'Productivity' and 'Experience and knowledge' as important aspects of a 'good farmer' identity. However, 'Productivity' in their case was strongly linked to 'Environmental responsibility, respect, and awareness' in the case of CA farmers. While farmers of both groups identified 'Stewardship of land' as a concept, CA farmers also identified 'Connection to the land' as a concept related to the 'good farmer' identity. This suggests a greater role of environmental values, particularly a sense of relation to the landscape, in decision-making for CA farmers. Chapman et al. (2019) suggested that farmers' participation in farmland conservation activities is improved when schemes align to their values, including a need to undertake active management of the landscape. Integrating these values into agricultural policies may enhance the uptake of CA, for example through the promotion of environmental achievements related to soil and water conservation (Sutherland & Darnhofer, 2012). In addition, CA farmers have other strategies to demonstrate good farming practices, as shown by the prominent role played by 'New practices, technologies, and innovations'. Openness to change and innovation is a key motivator for CA in the Mediterranean (Mrabet et al., 2022), and has been linked to younger and more educated farmers (Ahnström et al., 2009; Dhraief et al., 2019; Koutsou et al., 2014).

4.3. Study limitations

Our results indicated that farmers' mental models differed based on their geographical origins, but an in-depth analysis of this variable was beyond the scope of the present study. Thus, various aspects of individual, cultural and geographical background are not fully considered in our understanding of 'good soil management' and 'good farmer' identity. Overall, it appears that central soil conservation concepts such as 'Soil conservation and improvement' and 'Soil fertility and organic matter' were primarily addressed by Spanish farmers whereas Moroccan and Tunisian farmers addressed these issues infrequently. Accordingly, Moroccan and Tunisian farmers either have a more limited perception of soil conservation relative to Spanish farmers or do not consider these aspects to be relevant drivers in their soil management decisions.

As the responses were translated from the local language into English, any deviation from the original could result in a loss or variation of the meaning. Further, in some cases the dataset contained insufficient verbatim responses, as they were recorded mainly as keywords rather than as complete sentences. This resulted in homogenous responses that did not allow for* the possibility of interpreting subtexts. For some responses, clear differentiation of these codes was not possible, and multiple codes were assigned. For example, many farmers stated that being a 'good farmer' means 'knowing when to do the tasks'. Such responses were coded with both 'Right timing' and 'Experience and knowledge'. Additionally, the fact that the 'good soil management' question was asked in tandem with the 'good farmer' identity question may mean that concepts relating to soil management appeared in the responses to farmer identity. If the two questions were asked separately or in a different context, the responses may have been different. Finally, the methodology did not involve an in-depth qualitative analysis of responses or of the individual, cultural, and geographical backgrounds of participants. Considering these limitations, the concept networks elicited herein provide insights into Mediterranean farmers' understandings of the two concepts as a collective, and do not capture differences at the individual level. Our targeted sampling of farmers means that we do not claim to represent the wider population in our sample regions and therefore our results may not be applicable to other agricultural communities. Further regional differentiation in the mental models, and wider sampling in future studies is thus recommended.

5. Conclusions

Our study allowed us to derive three major insights. First, the concept of 'Crop rotation' was central to the understanding of 'good soil management' dor both conventional and CA farmers, and may thus offer an 'entry point' for encouraging conventional farmers to implement CA practices more comprehensively. Second, CA farmers related 'good soil management' to central features of CA (such as no tillage and crop rotation) together with an emphasis on the structure, fertility, and conservation of soils. In contrast, conventional farmers understood 'good soil management' as a combination of tillage with other key components of conventional agriculture, such as use of mineral fertilizers and pesticides and the presence of clean fields. Despite commonalities, our survey data revelas that the mental models of these two farmer groups are indeed different, suggesting that efforts to promote or reinforce CA need to be tailored to address the key themes identified in the divergent mental models. Third, there was greater agreement between the two groups regarding what constitutes being a 'good farmer' with the concepts of 'Productivity' and 'Experience and knowledge' being central to both groups, even though CA farmers appeared to have a more multifunctional perception of good farming. We conclude that such coherence offers additional entry points for promoting the adoption of CA, particularly by alluding to potential gains in productivity.

Converting to CA represents a radical change for farmers, not only on the technical level but also on the psychological level. Involving reduced plough usage, the introduction of permanent soil cover, and diversified crop rotations, CA potentially competes with internal held understandings of what 'good soil management' practices are and what constitutes a 'good farmer'. Our study sheds light on the most important concepts that make up these understandings among Mediterranean farmers. Understanding farmers' mental models surrounding these concepts s crucial for developing effective strategies for promoting CA across the Mediterranean, a region that is undergoing critical soil degradation coupled with severe drought and climate destabilization.

We not only demonstrated which concepts are important for Mediterranean farmers, but also how these concepts are cognitively linked. For example, a link was revealed between 'Mineral fertiliser' and 'Tillage' for conventional farmers, and 'Productivity' was closely linked to 'Environmental responsibility and awareness' for CA farmers. These linkages form a picture of how soil management is conceived and reveal the need for greater awareness of how soil function affects productivity. In addition, we revealed the different forms of capital, including economic, social, and cultural capital that play a role in forming Mediterranean farmers' identities. Considering these forms of capital by, for example, building strong communities around shared experiences with CA practices, could also support the adoption of CA. In this study, we captured a snapshot of farmers' understandings but soil conservation is a long-term endeavour that requires consistent engagement and support. Future research could integrate considerations of long-term vs. short-term thinking into farmers' mental models around soil, and might further investigate how climate adaptation is cognitively linked to soil management among farmers.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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Data availability statement

The data is available upon request to the authors.

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References

Aguilera, E., Lassaletta, L., Gattinger, A., & Gimeno, B. S. (2013). Managing soil carbon for climate change mitigation and adaptation in Mediterranean cropping systems: A meta-analysis. *Agriculture, Ecosystems & Environment*, *168*, 25–36. https://doi.org/10.1016/j.agee.2013.02.003

Ahnström, J., Höckert, J., Bergeå, H. L., Francis, C. A., Skelton, P., & Hallgren, L. (2009). Farmers and nature conservation: What is known about attitudes, context factors and actions affecting conservation?. *Renewable Agriculture and Food Systems*, *24*(1), 38–47. https://doi.org/10.1017/S1742170508002391

Arif, T. (2015). The mathematics of social network analysis: Metrics for academic social networks. *International Journal of Computer Applications in Technology and Research*, *4*, 889–893. https://doi.org/10.7753/ijcatr0412.1003

Aznar-Sánchez, J. A., Velasco-Muñoz, J. F., López-Felices, B., & del Moral-Torres, F. (2020). Barriers and facilitators for adopting sustainable soil. *MDPI- Agron*, *10*(4), 1–18.

Bouatrous, A., Harbaoui, K., Karmous, C., Gargouri, S., Souissi, A., Belguesmi, K., Cheikh Mhamed, H., Gharbi, M. S., & Annabi, M. (2022). Effect of wheat monoculture on durum wheat yield under rainfed sub-humid Mediterranean climate of Tunisia. *Agronomy*, *12*(6), 1453. https://doi.org/10.3390/agronomy12061453

Bourdieu, P. (1984). *Distinction: A social critique of the judgement of taste*. Routledge.

Bower, K. M. (2003). When to use Fisher's exact test. *American Society for Quality, Six Sigma Forum Magazine*, *2*(4), 35–37.

Bowles, T. M., Mooshammer, M., Socolar, Y., Calderón, F., Cavigelli, M. A., Culman, S. W., Deen, W., Drury, C. F., Garcia y Garcia, A., Gaudin, A. C., Harkcom, W. S., Lehman, R. M., Osborne, S. L., Robertson, G. P., Salerno, J., Schmer, M. R., Strock, J., & Grandy, A. S. (2020). Long-term evidence shows that crop-rotation diversification increases agricultural resilience to adverse growing conditions in North America. *One Earth*, *2*(3), 284–293. https://doi.org/10.1016/j.oneear.2020.02.007

Burton, R. J. F. (2004). Seeing through the 'good farmer's' eyes: Towards developing an understanding of the social symbolic value of 'productivist' behaviour. *Sociologia Ruralis*, *44*(2), 195–215. https://doi.org/10.1111/j.1467-9523.2004.00270.x

Burton, R. J. F., Forney, J., Stock, P., & Sutherland, L. A. (2021). *The good farmer: Culture and identity in food and agriculture* (1st ed.). Routledge.

Burton, R. J. F., Kuczera, C., & Schwarz, G. (2008). Exploring farmers' cultural resistance to voluntary agri-environmental schemes. *Sociologia Ruralis*, *48*(1), 16–37. https://doi.org/10.1111/j.1467-9523.2008.00452.x

Burton, R. J. F., & Paragahawewa, U. H. (2011). Creating culturally sustainable agri-environmental schemes. *Journal of Rural Studies*, *27*(1), 95–104. https://doi.org/10.1016/j.jrurstud.2010.11.001

Carley, K., & Palmquist, M. (1992). Extracting, representing, and analyzing mental models. *Social Forces*, *70*(3), 601–636. https://doi.org/10.1093/sf/70.3.601

Ceglar, A., Zampieri, M., Toreti, A., & Dentener, F. (2019). Observed northward migration of agro-climate zones in Europe will further accelerate under climate change. *Earth's Future*, *7*(9), 1088–1101. https://doi.org/10.1029/2019EF001178

Cerdà, A., Rodrigo-Comino, J., Yakupoğlu, T., Dindaroğlu, T., Terol, E., Mora-Navarro, G., Arabameri, A., Radziemska, M., Novara, A., Kavian, A., Vaverková, M. D., Abd-Elmabod, S. K., Hammad, H. M., & Daliakopoulos, I. N. (2020). Tillage versus no-tillage. Soil properties and hydrology in an organic persimmon farm in Eastern Iberian Peninsula. *Water*, *12*(6), 1539. https://doi.org/10.3390/w12061539

Chapman, M., Satterfield, T., & Chan, K. M. A. (2019). When value conflicts are barriers: Can relational values help explain farmer participation in conservation incentive programs? *Land Use Policy*, *82*, 464–475. https://doi.org/10.1016/j.landusepol.2018.11.017

Christiansen, S., Ryan, J., Singh, M., Ates, S., Bahhady, F., Mohamed, K., Youssef, O., & Loss, S. (2015). Potential legume alternatives to fallow and wheat monoculture for Mediterranean environments. *Crop and Pasture Science*, *66*(2), 113. https://doi.org/10.1071/CP14063

Cicek, H., Topp, E., Plieninger, T., Blanco-Moreno, J. M., Gultekin, I., Cheikh Mohamed, H., & El Gharras, O. (2023). A critical assessment of conservation agriculture among smallholders in the Mediterranean region : Adoption pathways inspired by agroecological principles. *Agronomy for Sustainable Development*, *43*(6), 72. https://doi.org/10.1007/s13593-023-00926-4

Cramer, W., Guiot, J., Fader, M., Garrabou, J., Gattuso, J. P., Iglesias, A., Lange, M. A., Lionello, P., Llasat, M. C., Paz, S., Peñuelas, J., Snoussi, M., Toreti, A., Tsimplis, M. N., & Xoplaki, E. (2018). Climate change and interconnected risks to sustainable development in the Mediterranean. *Nature Climate Change*, *8*(11), 972–980. https://doi.org/10.1038/s41558-018-0299-2

Dhraief, M. Z., Bedhiaf, S., Dhehibi, B., Oueslati-Zlaoui, M., Jebali, O., & Ben-Youssef, S. (2019). Factors affecting innovative technologies adoption by livestock holders in arid area of Tunisia. *New Medit*, *18*(4), 3–18. https://doi.org/10.30682/nm1904a

Di Bene, C., Dolores Gómez-López, M., Francaviglia, R., Farina, R., Blasi, E., Martínez-Granados, D., & Calatrava, J. (2022). Barriers and opportunities for sustainable farming practices and crop diversification strategies in Mediterranean cereal-based systems. *Frontiers in Environmental Science*, *10*, 861225. https://doi.org/10.3389/fenvs.2022.861225

FAO. (2016). Conservation agriculture. Retrieved August 29, 2022, from https://www.fao.org/3/cb8350en/cb8350en.pdf

Ferreira, C. S. S., Seifollahi-Aghmiuni, S., Destouni, G., Ghajarnia, N., & Kalantari, Z. (2022). Soil degradation in the European Mediterranean region: Processes, status and consequences. *Science of The Total Environment*, *805*, 150106. https://doi.org/10.1016/j.scitotenv.2021.150106

Fouzai, A., Smaoui, M., Frija, A., & Dhehibi, B. (2018). Adoption of conservation agriculture technologies by smallholder farmers in the semiarid region of Tunisia: Resource constraints and partial adoption. *Journal of New Sciences Sustainable Livestock Management*, *6*(1), 105–114.

Friedrich, T., & Kassam, A. H. (2009). Adoption of conservation agriculture technologies: Constraints and opportunities. In *Proceedings of the 4th World Congress on Conservation Agriculture: Innovations for Improving Efficiency, Equity and Environment*. *World Congress on Conservation Agriculture* (pp. 257–264).

Halbrendt, J., Gray, S. A., Crow, S., Radovich, T., Kimura, A. H., & Tamang, B. B. (2014). Differences in farmer and expert beliefs and the perceived impacts of conservation agriculture. *Global Environmental Change*, *28*, 50–62. https://doi.org/10.1016/j.gloenvcha.2014.05.001

Hanneman, R. A., & Riddle, M. (2011a). A brief introduction to analyzing social network data. In J. Scott & P. J. Carrington (Eds.), *The SAGE handbook of social network analysis* (pp. 331–339). SAGE.

Hanneman, R. A., & Riddle, M. (2011b). Concepts and measures for basic network analysis. In J. Scott & P. J. Carrington (Eds.), *The SAGE handbook of social network analysis* (pp. 340–369). SAGE.

Hoffman, M., Lubell, M., & Hillis, V. (2014). Linking knowledge and action through mental models of sustainable agriculture. *Proceedings of the National Academy of Sciences*, *111*(36), 13016–13021. https://doi.org/10.1073/pnas.1400435111

Iglesias, A., Mougou, R., Moneo, M., & Quiroga, S. (2011). Towards adaptation of agriculture to climate change in the Mediterranean. *Regional Environmental Change*, *11*(S1), 159–166. https://doi.org/10.1007/s10113-010-0187-4

Ingram, J., Fry, P., & Mathieu, A. (2010). Revealing different understandings of soil held by scientists and farmers in the context of soil protection and management. *Land Use Policy*, *27*(1), 51–60. https://doi.org/10.1016/j.landusepol.2008.07.005

Jones, N. A., Ross, H., Lynam, T., Perez, P., & Leitch, A. (2011). Mental models: An interdisciplinary synthesis of theory and methods. *Ecology and Society*, *16*(1), 46. https://doi.org/10.5751/ES-03802-160146

Kassam, A., Derpsch, R., & Friedrich, T. (2020). Development of conservation agriculture systems globally. In A. Kassam (Ed.), *Advances in conservation agriculture* (pp. 30–46). Burleigh Dodds Science Publishing. https://doi.org/10.1515/9783112318577-003

Kassam, A., Friedrich, T., Derpsch, R., Lahmar, R., Mrabet, R., Basch, G., González-sánchez, E. J., & Serraj, R. (2012). Conservation agriculture in the dry Mediterranean climate. *Field Crops Research*, *132*, 7–17. https://doi.org/10.1016/j.fcr.2012.02.023

Kassam, A., Friedrich, T., Shaxson, F., & Pretty, J. (2009). The spread of conservation agriculture: Justification, sustainability and uptake. *International Journal of Agricultural Sustainability*, *7*(4), 292–320. https://doi.org/10.3763/ijas.2009.0477

Koutsou, S., Partalidou, M., & Ragkos, A. (2014). Young farmers' social capital in Greece: Trust levels and collective actions. *Journal of Rural Studies*, *34*, 204–211. https://doi.org/10.1016/j.jrurstud.2014.02.002

Kuckartz, U., & Rädiker, S. (2019). *Analyzing qualitative data with MAXQDA* (pp. 1–290). Springer International Publishing.

Lagacherie, P., Álvaro-Fuentes, J., Annabi, M., Bernoux, M., Bouarfa, S., Douaoui, A., Grünberger, O., Hammani, A., Montanarella, L., Mrabet, R., Sabir, M., & Raclot, D. (2018). Managing Mediterranean soil resources under global change: Expected trends and mitigation strategies. *Regional Environmental Change*, *18*(3), 663–675. https://doi.org/10.1007/s10113-017-1239-9

Lahmar, R. (2010). Adoption of conservation agriculture in Europe. Lessons of the KASSA project. *Land Use Policy*, *27*(1), 4–10. https://doi.org/10.1016/j.landusepol.2008.02.001

Lalani, B., Aminpour, P., Gray, S., Williams, M., Büchi, L., Haggar, J., Grabowski, P., & Dambiro, J. (2021). Mapping farmer perceptions, Conservation agriculture practices and on-farm measurements: The role of systems thinking in the process of adoption. *Agricultural Systems*, *191*, 103171. https://doi.org/10.1016/j.agsy.2021.103171

Lavoie, A., & Wardropper, C. B. (2021). Engagement with conservation tillage shaped by "good farmer" identity. *Agriculture and Human Values*, *38*(4), 975–985. https://doi.org/10.1007/s10460-021-10205-1

Lee, H., Lautenbach, S., Nieto, A. P. G., Bondeau, A., Cramer, W., & Geijzendorffer, I. R. (2019). The impact of conservation farming practices on Mediterranean agro-ecosystem services provisioning—a meta-analysis. *Regional Environmental Change*, *19*(8), 2187–2202. https://doi.org/10.1007/s10113-018-1447-y

Lynam, T., & Brown, K. (2012). Mental models in human-environment interactions: Theory, policy implications, and methodological explorations. *Ecology and Society*, *17*(3), 22–25. https://doi.org/10.5751/ES-04257-170324

Mayring, P. (2014). *Qualitative content analysis: Theoretical foundation, basic procedures and software solution, forum qualitative Sozialforschung/Forum: Qualitative social research*. Leibniz Institute for Social Sciences.

McGuire, J., Morton, L. W., & Cast, A. D. (2013). Reconstructing the good farmer identity: Shifts in farmer identities and farm management practices to improve water quality. *Agriculture and Human Values*, *30*(1), 57–69. https://doi.org/10.1007/s10460-012-9381-y

McGuire, J. M., Morton, L. W., Arbuckle, J. G., & Cast, A. D. (2015). Farmer identities and responses to the social-biophysical environment. *Journal of Rural Studies*, *39*, 145–155. https://doi.org/10.1016/j.jrurstud.2015.03.011

Mediterranean experts on Climate and environmental Change (MedECC). (2020). Climate and environmental change in the Mediterranean basin – current situation and risks for the future. *First Mediterranean Assessment Report*.

Mrabet, R., Bahri, H., Zaghouane, O., Cheikh M'Hamed, H., El-Areed, S. R. M., & El-Enin, M. M. A. (2022). Adoption and spread of conservation agriculture in North Africa. In A. Kassam (Ed.), *Advances in conservation agriculture volume 3: Adoption and spread* (pp. 1–61). Burleigh Dodds Science Publishing. https://doi.org/10.1080/00207233.2020.1805879

Newman, M. E. J. (2008). Mathematics of networks. In S. N. Durlauf & L. E. Blume (Eds.), *The new Palgrave dictionary of economics* (pp. 1–8). Palgrave Macmillan UK.

Pannell, D. J., Llewellyn, R. S., & Corbeels, M. (2014). The farm-level economics of conservation agriculture for resource-poor farmers. *Agriculture, Ecosystems & Environment*, *187*, 52–64. https://doi.org/10.1016/j.agee.2013.10.014

Pannell, D. J., Marshall, G. R., Barr, N., Curtis, A., Vanclay, F., & Wilkinson, R. (2006). Understanding and promoting adoption of conservation practices by rural landholders. *Australian Journal of Experimental Agriculture*, *46*(11), 1407–1424. https://doi.org/10.1071/EA05037

Pittelkow, C. M., Liang, X., Linquist, B. A., Van Groenigen, L. J., Lee, J., Lundy, M. E., Van Gestel, N., Six, J., Venterea, R. T., & Van Kessel, C. (2015a). Productivity limits and potentials of the principles of conservation agriculture. *Nature*, *517*(7534), 365–368. https://doi.org/10.1038/nature13809

Pittelkow, C. M., Linquist, B. A., Lundy, M. E., Liang, X., van Groenigen, K. J., Lee, J., van Gestel, N., Six, J., Venterea, R. T., & van Kessel, C. (2015b). When does no-till yield more? A global meta-analysis. *Field Crops Research*, *183*, 156–168. https://doi.org/10.1016/j.fcr.2015.07.020

Powlson, D. S., Stirling, C. M., Jat, M. L., Gerard, B. G., Palm, C. A., Sanchez, P. A., & Cassman, K. G. (2014). Limited potential of no-till agriculture for climate change mitigation. *Nature Climate Change*, *4*(8), 678–683. https://doi.org/10.1038/nclimate2292

Prager, K., & Curfs, M. (2016). Using mental models to understand soil management. *Soil Use and Management*, *32*(1), 36–44. https://doi.org/10.1111/sum.12244

Rädiker, S., & Kuckartz, U. (2020). *Focused analysis of qualitative interviews with MAXQDA: Step by step*. Maxqda Press.

Raedeke, A. H., Green, J. J., Hodge, S. S., & Valdivia, C. (2003). Farmers, the practice of farming and the future of agroforestry: An application of Bourdieu's concepts of field and habitus. *Rural Sociology*, *68*(1), 64–86. https://doi.org/10.1111/j.1549-0831.2003.tb00129.x

Rust, N. A., Ptak, E. N., Graversgaard, M., Iversen, S., Reed, M. S., de Vries, J. R., Ingram, J., Mills, J., Neumann, R. K., Kjeldsen, C., Muro, M., & Dalgaard, T. (2023). Social capital factors affecting uptake of sustainable soil management practices: A literature review. *Emerald Open Research*, *1*(10), 8. https://doi.org/10.35241/emeraldopenres.13412.2

Ryan, J., Ibrikci, H., Sommer, R., & McNeill, A. (2009). Nitrogen in rainfed and irrigated cropping systems in the Mediterranean region. *Advances in Agronomy*, *104*, 53–136. https://doi.org/10.1016/S0065-2113(09)04002-4

Sardaro, R., Faccilongo, N., Contò, F., & La Sala, P. (2021). Adaption actions to cope with climate change: Evidence from farmers' preferences on an agrobiodiversity conservation programme in the Mediterranean area. *Sustainability*, *13*, 5977. https://doi.org/10.3390/su13115977

Sastre, B., Barbero-Sierra, C., Bienes, R., Marques, M. J., & García-Díaz, A. (2017). Soil loss in an olive grove in Central Spain under cover crops and tillage treatments, and farmer perceptions. *Journal of Soils and Sediments*, *17*(3), 873–888. https://doi.org/10.1007/s11368-016-1589-9

Saunders, F. P. (2016). Complex shades of green: Gradually changing notions of the 'good farmer' in a Swedish context. *Sociologia Ruralis*, *56*(3), 391–407. https://doi.org/10.1111/soru.12115

Schmitzberger, I., Wrbka, T., Steurer, B., Aschenbrenner, G., Peterseil, J., & Zechmeister, H. G. (2005). How farming styles influence biodiversity maintenance in Austrian agricultural landscapes. *Agriculture, Ecosystems & Environment*, *108*(3), 274–290. https://doi.org/10.1016/j.agee.2005.02.009

Skuras, D., & Psaltopoulos, D. (2012). A broad overview of the main problems derived from climate change that will affect agricultural production in the Mediterranean area. In A. Meybeck (Ed.), *Building Resilience for Adaptation to Climate Change in the Agriculture Sector: Proceedings of a Joint FAO/OECD Workshop 23–24 April 2012* (pp. 217–260). Food and Agriculture Organization of the United Nations.

Sutherland, L. A., & Darnhofer, I. (2012). Of organic farmers and "good farmers": Changing habitus in rural England. *Journal of Rural Studies*, *28*(3), 232–240. https://doi.org/10.1016/j.jrurstud.2012.03.003

van der Ploeg, J. D. (2022). *The sociology of farming: Concepts and methods*. Routledge.

Vanino, S., Di Bene, C., Piccini, C., Fila, G., Pennelli, B., Zornoza, R., Sanchez-Navarro, V., Álvaro-Fuentes, J., Hüppi, R., Six, J., & Farina, R. (2022). A comprehensive assessment of diversified cropping systems on agro-environmental sustainability in three Mediterranean long-term field experiments. *European Journal of Agronomy*, *140*, 126598. https://doi.org/10.1016/j.eja.2022.126598

Vastola, A., Zdruli, P., D'Amico, M., Pappalardo, G., Viccaro, M., Di Napoli, F., Cozzi, M., & Romano, S. (2017). A comparative multidimensional evaluation of conservation agriculture systems: A case study from a Mediterranean area of Southern Italy. *Land Use Policy*, *68*, 326–333. https://doi.org/10.1016/j.landusepol.2017.07.034

Wang, T., Jin, H., Fan, Y., Obembe, O., & Li, D. (2021). Farmers' adoption and perceived benefits of diversified crop rotations in the margins of U.S. Corn Belt. *Journal of Environmental Management*, *293*, 112903. https://doi.org/10.1016/j.jenvman.2021.112903

Wei, W., Pfeffer, J., Reminga, J., & Carley, K. M. (2011). *Handling weighted, asymmetric, self-looped, and disconnected networks in ORA*. http://doi.org/10.2139/ssrn.2729311

Westerink, J., Pleijte, M., Schrijver, R., van Dam, R., de Krom, M., & de Boer, T. (2021). Can a 'good farmer' be nature-inclusive? Shifting cultural norms in farming in The Netherlands. *Journal of Rural Studies*, *88*, 60–70. https://doi.org/10.1016/j.jrurstud.2021.10.011

Wittstock, F., Paulus, A., Beckmann, M., Hagemann, N., & Baaken, M. C. (2022). Understanding farmers' decision-making on agri-environmental schemes: A case study from Saxony, Germany. *Land Use Policy*, *122*, 106371. https://doi.org/10.1016/j.landusepol.2022.106371